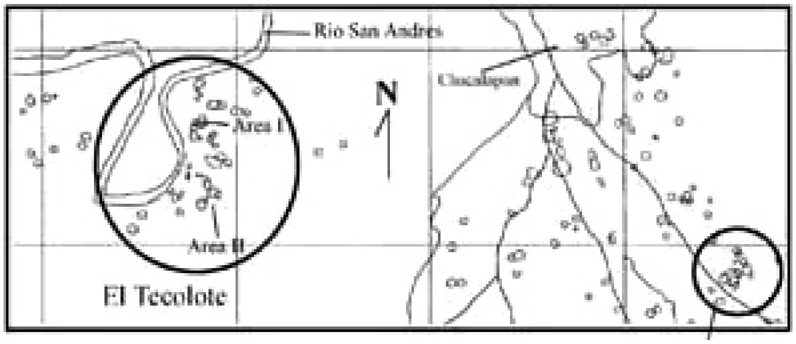
# The Chacalapan Geophysical Survey, Veracruz, México




**Research Year**: 2000
**Culture**: Aztec
**Chronology**: Post Classic
**Location**: Chacalapan, Veracruz, México
**Sites**: Cinco Cerros and El Tecolote

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## Abstract

The Chacalapan Geophysical Survey (CGS) took place surrounding the modern town of Chacalapan, Veracruz, México during March and May 2000. The main goals of the CGS were to aid ongoing work (Chacalapan Archaeological Project) aimed at examining the degree of Aztec control over the region and establishing a Postclassic ceramic chronology. The CGS helped accomplish these goals by locating domestic deposits and burned areas through magnetic gradiometry and electrical resistivity. Resistivity was employed also to take "soundings" at varying depths in excavation walls and over flat ground. This allowed the researchers to infer the type (sand, silt, clay) of the substrate. The survey produced a body of maps showing large, contiguous areas of the subsurface. The magnetic survey, while successfully locating several important deposits, was partially hindered by modern agricultural land use that contributed metal debris to the area. The data from six test excavations enabled us to refine our interpretive methodology and eliminate signals caused by intrusive metal. The production of accurate magnetic maps was a goal in itself. Those maps will enable the Chacalapan Archaeological Project to better target areas for excavation in the future and thus save time and money.

## Resumen

El Estudio Geofísico de Chacalapan (EGC) tuvo lugar en los alrededores del pueblo moderno de Chacalapan, en Veracruz, México, durante los meses de marzo y mayo del año 2000. Los objetivos principales del EGC fueron los de ayudar en el trabajo en curso (Proyecto Arqueológico Chacalapan), cuyo fin es revisar el grado de control azteca sobre la región y establecer una cronología cerámica posclásica. El EGC ayudó a concretar estos objetivos a través del hallazgo de depósitos domésticos y áreas quemadas, ocurrido gracias la gradiometría magnética y la resistividad eléctrica. La resistividad también se empleó para realizar "sondeos" a distintas profundidades en los muros de las excavaciones, como así también sobre terreno plano. Esto permitió que los investigadores pudieran inferir el tipo del sustrato (arena, limo, arcilla). El estudio produjo un cuerpo de mapas que mostraron áreas extensas y contiguas de la subsuperficie. El reconocimiento magnético, a la vez que tuvo éxito en la localización de varios yacimientos de importancia, quedó parcialmente obstaculizado por el uso actual de las tierras agrícolas, que ha dado origen a la presencia de desechos metálicos en la zona. Los datos obtenidos en seis excavaciones de prueba nos permitieron ajustar nuestra metodología interpretativa y eliminar las señales causadas por los metales intrusivos. La producción de mapas magnéticos precisos fue un objetivo en sí mismo. Dichos mapas permitirán que el Proyecto Arqueológico Chacalapan pueda decidir con mayor precisión qué áreas se habrán de excavar en el futuro, ahorrando, por lo tanto, tiempo y fondos.



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## Introduction

Recent research (Berdan *et al*., 1996) has suggested that the southern Veracruz area surrounding the modern town of Chacalapan was located on the outside edge of the Aztec Empire. Archaeological work in this area then has the potential to add to our understanding of core-periphery interaction in an imperial state society. The area is currently under study by the Chacalapan Archaeological Project (CAP) which is headed by Chantal Esquivias, Boston University (Figure 1). Funding was granted by FAMSI for a geophysical survey to be done in conjunction with the CAP. The Chacalapan Geophysical Survey (CGS) was undertaken to aid the CAP by locating middens and domestic areas.

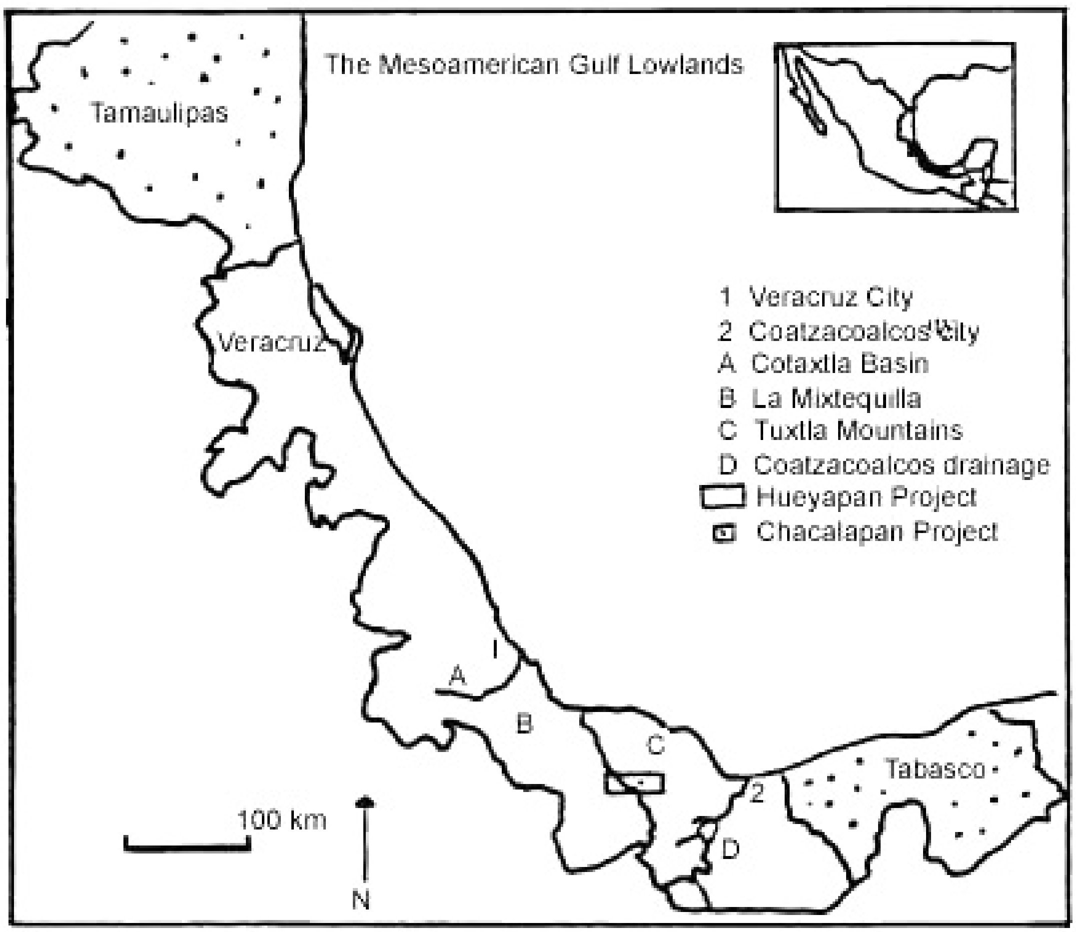



**Figure 1: The Gulf Coast Lowlands.**

The main goals of the CAP were to identify any Imperial Aztec presence or influence in the southern Veracruz area and to redefine the Postclassic ceramic chronology for the area. Central to both of these goals was the need to locate ceramics from a wide range of contexts. The most common visible archaeological features in the area are large earthen mounds. The CAP targeted some of these features to determine their function and period of construction and occupation. These structures were also expected to yield diagnostic artifacts that could show any Aztec presence. The CAP also desired to recover material from off-mound midden contexts. Due to the relatively small size of the project's test excavations, a technique to precisely locate subsurface features prior to excavation was needed to save time and effort. We believed that high-resolution geophysical survey was the ideal application for this problem.

## Methodology

Our geophysical work in and around Chacalapan was conducted over two periods. The first period consisted of approximately three and one half weeks during the month of March 2000. During this period we conducted extensive magnetic survey. This work concentrated on covering a maximum amount of area in an effort to locate as many features as possible. Using maps generated in the field from survey results, some suspected features were excavated, but we also decided to wait for more intensive data processing before testing all interpreted anomalies. During the second period, two weeks during May 2000, we used the processed data to generate detailed maps to locate suspected features that were not immediately visible in the raw data. Certain possible archaeological deposits were then tested with electrical resistivity in an effort to further characterize them. In addition, resistivity testing was performed on the walls of an open excavation unit in order to better refine the understanding of the area's stratigraphic record. This section details the reasons for our choosing particular methods and equipment. A discussion of the techniques of magnetic gradiometry and electrical resistivity is presented, followed by a discussion of our field methods and computer processing methods.

### *Magnetic Gradiometry*

After a preliminary study of the region's archaeological remains and underlying geology during the Proyecto Arqueológico Hueyapan in 1998, we selected magnetometry and electrical resistivity as the two methods best suited to meet our goals. Magnetometry surveys are used to measure minute variations, measured in nanoTeslas (nT), in the Earth's magnetic properties across an area. Archaeological features are detected through the contrast between their magnetic properties and the magnetic properties of the surrounding soil. Ferrous metals, dense deposits of fired ceramics, and burned areas (kilns, hearths) are readily detectable through magnetics (Breiner, 1973; Weymouth, 1986). Furthermore, areas of topsoil disturbance or organic input (whether ancient or modern) are also detectable. Depending on the strength of the source of magnetic interference the features as deep as 2.5-3 meters may be detected. Very slight changes in ground chemistry may also influence magnetic results. Areas of a site may have a higher concentration of ferrous minerals in the soil that could affect readings over a large area and need to be identified and dealt with during data processing and interpretation.

A major problem with magnetometry is that the Earth's magnetic field is not constant throughout the day. A magnetometer records what is commonly known as the total field. The total field is the magnetic susceptibility of the soil, buried features, normal Earth magnetism, and influences from the Sun. Magnetic storms and sunspot activity can cause short term changes in the strength of the magnetic field that are orders of magnitude greater than changes caused by archaeological features. The total field can be in the range of 30,000 - 50,000 nT, while archaeological features may only show anomalies on the order of several nT or fractions of nT. The timing and intensity of these storms are wholly unpredictable. Furthermore, the Earth's normal magnetic field changes in intensity throughout the day. This is called the diurnal effect, and can severely hamper data quality. In order to remove these influences, archaeological geophysicists employ the technique of magnetic gradiometry. Gradiometry employs a pair of linked magnetometers set to record readings at exactly the same time. One magnetometer is positioned above the other so as to read only the Earth's field and any stellar interference. The lower magnetometer reads as the upper one but also reads the influences from the ground. One dataset may then be subtracted from the other, thus filtering out most of the background noise and leaving only the influence of the ground.

A Geometrics G-858 Cesium Vapor Magnetometer configured in gradient mode was rented for a total field time of 30 days. The Geometrics G-858 represents the current state of the art in high-resolution magnetics and is capable of extremely fast, accurate data collection and has been employed successfully in archaeological applications (Watters, personal communication; Hervanger, 1996). Gradiometry was our primary technique and was employed as a prospecting tool for large area coverage. When possible, areas were divided into 40 x 20-m grids. It was preferable to survey as large, regularly shaped area as possible so that newly surveyed grids could be easily fitted to previous grid. However, with real world field conditions in mind we selected an instrument which has the capability to survey irregularly sized and shaped areas if we were constricted as a result of topography or ground cover (Geometrics, 1995). The ground cover over the bulk of the surveyed area was low pasture grass and thus was no impediment. Wherever bushes or trees were present, their location was marked on maps so as to identify them in the data. The majority of the terrain was relatively flat. In instances where a slope was surveyed, transects were run in one direction only. This was to keep the sensors at a constant distance from the ground surface to eliminate the substantial error that occurs when sensor distance to ground varies. Flat areas were surveyed in a zigzag pattern; with the end of one transect being the beginning of the adjacent one. The G-858 internal software is specifically designed for, and anticipates this pattern and surveying in this manner is extremely rapid. The survey time for each grid was approximately 1 hour. Within each grid the magnetic field was sampled every 10-cm along traverses spaced 50 cm apart. These survey parameters represent the very high level of resolution needed to locate prehistoric features. Data was downloaded into Geometrics' MagMap96 software for preliminary processing and then into Golden Software's Surfer Version 6.0 GIS for intensive processing, analysis, and display of results.

Data processing was necessary to get the magnetic information into an interpretable format. The G-858 has an internal memory system that records readings for both sensors (the total fields) as well as the physical position of the reading in the survey area. The information was downloaded into laptop computers using Geometrics MagMap96 software. MagMap is instrument-specific software for downloading and analyzing magnetic data from Geometrics instruments. It provides a schematic representation of the survey area so that the operator can make sure all readings are in their correct spatial orientation, but the software has limited processing and interpretation capabilities. Once corrections to the spatial orientation of data points were made, the X and Y position of the survey points and the difference between the total fields as measured by the two sensors (the gradient) were exported to Surfer. In addition to performing the statistical computations necessary to process information, Surfer has the capability to deal with truly huge datasets. This was significant to our work because we wanted to concatenate (or fit together) all survey grids in a given area prior to processing. This would insure that mathematical functions would operate equally on the whole dataset. To illustrate the type of processing capability we needed, the larger of the two areas from the site of El Tecolote was made up of nearly one half million individual data points.

Once in Surfer, descriptive statistics were computed for each dataset and data were clipped outside of two standard deviations from the mean reading. This eliminated the influence of data "spikes." Spikes are readings that are found at the extremes of the dataset and are likely caused by instrument error or metallic surface debris such as bottle caps or cans. Their presence can obscure the more ephemeral signals that may be caused by archaeological features. It is still useful to examine the data carefully with the spikes present to discern if they may be archaeologically significant. Data were then reexamined with descriptive statistics to check if any drastic alteration of the mean occurred which could signal error. The clipped dataset was then gridded by Surfer with no interpolation. From this, contour and color image maps were produced. The displayed data range was manipulated to try to zero in on features. We produced final maps in Surfer for use in planning excavations. These maps were grayscale depictions and because magnetic readings have a positive and negative numerical component, extremes were identified by either red or blue. This allowed the computer to "stretch" its 256 shades of gray across a finer range and bring out more subtle detail. Anomalies were identified based on their shape. Regular shapes, or patterned geometries, rarely occur in the natural world and usually signal manmade features. Furthermore, discrete, highly magnetically susceptible features tend to cause a paired high/low reading called a dipole. Dipoles were also noted as possible archaeological features.

### *Electrical Resistivity*

Resistance surveys measure variations, expressed in ohms (Ω), in the electrical resistance of soil across a site or down through a column of earth. An electric current is introduced into the ground by a series of probes. The current travels through the ground to another series of probes that measure the potential difference. Electricity always seeks the path of least resistance so that if it encounters a highly resistant feature such as a stone wall, it will travel around it. A longer travel path will result in greater resistance. Electrical properties of a soil are primarily dependent on matrix type, compaction, moisture content, and objects buried within (Clark, 1996; DeVore and Heimmer, 1995). The ohm measurement is later calculated with respect to depth to normalize it so that readings taken as different depths can be compared, this is expressed as resistivity (ρ). This technique was used at Chacalapan primarily to test areas of magnetic interest, to take resistance "soundings" at different depths over a single location, and to test the walls of open excavations. In general, humic rich midden areas will tend to produce lower resistance values due to a higher concentration of organic ions and the presence of larger, moisture filled voids in coarse midden fill. Resistivity measurements vary tremendously with differing soil moisture, so there is much more interpretive guesswork involved with this technique. Since the same types of features produce anomalies in both techniques, resistivity correlates well with magnetics for certain types of features. Resistance soundings also enabled us to get an idea of the degree and type (sand, silt, clay) of the fill at varying depths. Resistivity was not used for large area survey, but only to "spot check" certain areas. By altering spacing between the soil probes, the instrument can be configured to read at differing depths. We used a Gossen Geohm 3 Soil Resistance Meter lent by the Boston University Department of Archaeology at no cost. The Geohm 3, while an older instrument, was well suited to our needs. It is small, has a compact power source, and features a manual probe configuration that allows easy surveying at multiple depths.

Over an area of magnetic interest, readings were taken at a consistent interval at several depths. For the majority of features, readings were spaced every 50 cm along a transect located to straddle the magnetic anomaly. Readings were then over a point taken at depths of .5, 1, and 1.5 meters. Readings were then converted into resistivity (ρ) measurements so as to be able to compare the composition of the soil through depth. No additional processing was needed.

## Interpretations

The Interpretations section is broken down into several parts consisting of descriptions of a test over buried basalt and the two surveyed sites: Cinco Cerros and El Tecolote (Figure 2). The test was conducted at El Tecolote and was meant to identify the magnetic signature of basalt. The bulk of the survey was performed at El Tecolote because that site was thought to be a better candidate for a Postclassic presence.

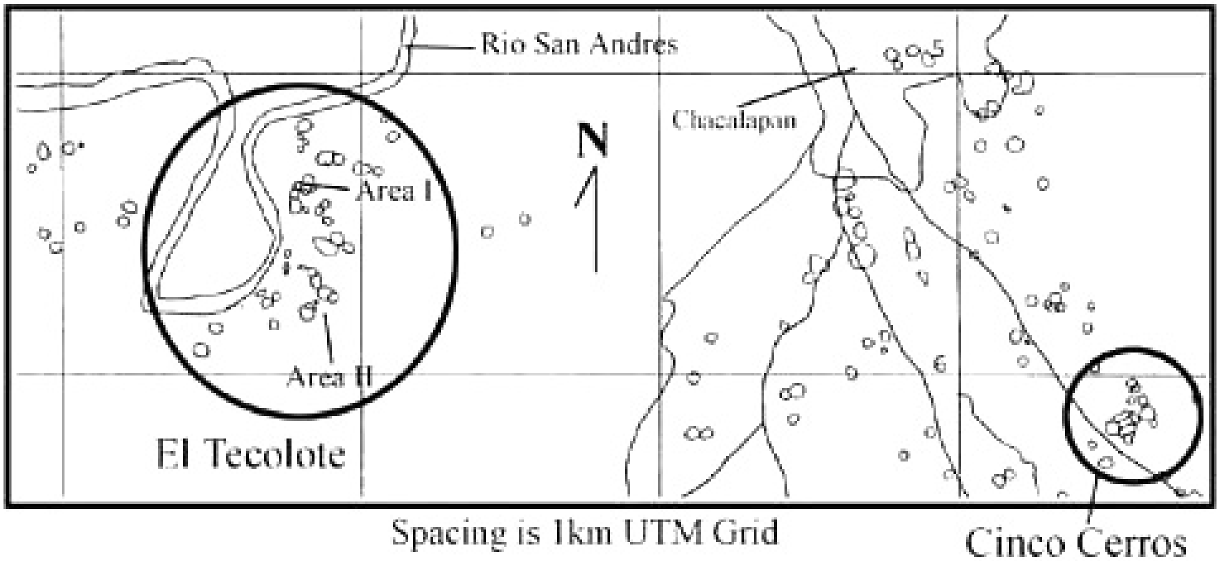



**Figure 2: Location of Sites.**

### *Basalt Test*

Basalt is a heavy volcanic stone used in prehispanic times for statuary and grinding stones called metates. It is available in quantity from the nearby Tuxtla Mountains and as small cobbles washed downriver from the mountains during violent rainy season storms. A 5 x 5-meter grid was laid out and tested with the magnetometer to ensure that there was not a strong anomaly present (Figure 3). A basalt cobble of approximately 15 kilograms was obtained from the nearby Río San Andrés rivercut and buried at a depth of 50 cm. The area was resurveyed. As can be seen from the map plot, the difference is dramatic. The basalt cobble produced a very distinct dipole reading.

### *Cinco Cerros*

The site of Cinco Cerros is located approximately 1 kilometer southeast of the town of Chacalapan. It is made up of a series of earthen mounds arranged around a central plaza (Figure 4). The CAP chose to focus on Cinco Cerros because it is a clearly defined formal plaza group with minimal evidence of looting. Excavations were undertaken to date the prehispanic occupation of the site. Presently the area is given over to cattle pasture and we expected to see metal debris from modern use in the data.

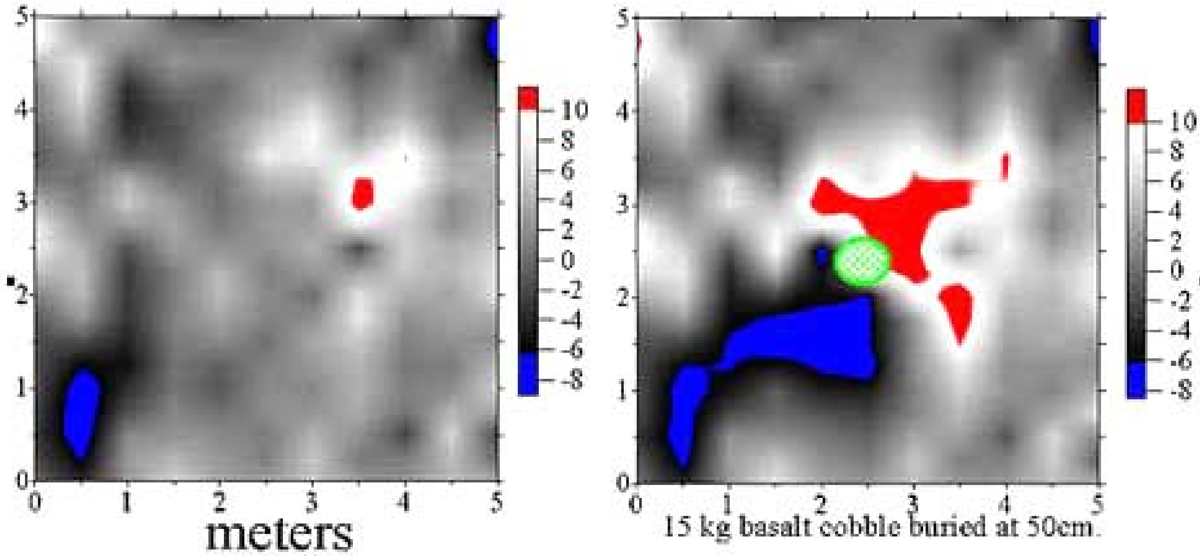



**Figure 3: Basalt Cobble Test.**

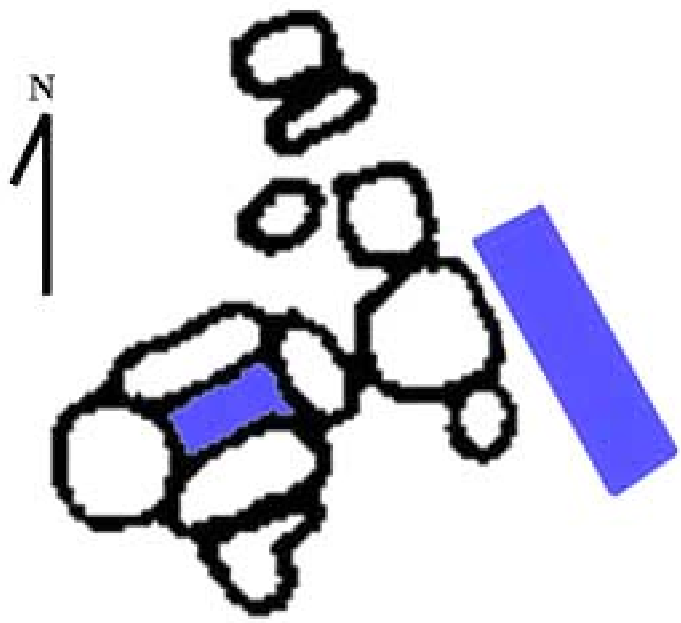
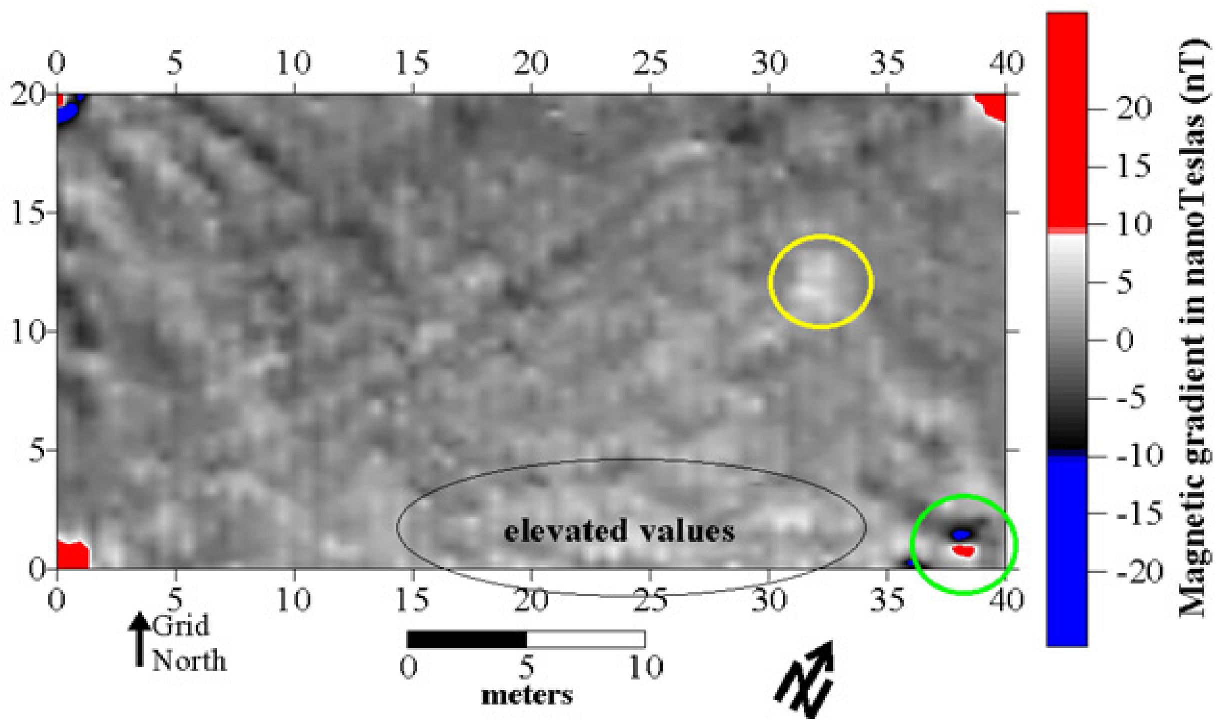



**Figure 4: Cinco Cerros. Surveyed areas are in blue.**

Two areas were surveyed for a total of 2720 $m^2$. The first area was comprised of a single 20 x 40-meter grid in the center of the plaza and covered approximately the entire plaza area. The grid transects were oriented 30 degrees west of North in order to coincide with the orientation of the plaza. Some instrument error was likely introduced by this practice, but we believe any error to be minimal. To ensure maximum resolution over this slightly uneven terrain, transects were surveyed in one direction only. An examination of the data revealed several interesting anomalies (Map 1). The most noticeable is the dipole in the grid southeastern corner (green circle). As noted earlier, a dipole is a paired high/low magnetic signature and usually indicates a very magnetically susceptible object. We sited a 1 x 2-meter test excavation (CAP excavation 23) over the area because it looked similar to the expected signature of a mass of basalt. Excavation revealed that the signature was in fact caused by a large steel staple of the sort that farmers use to secure wire to fence posts. The staple was found in stratum 2. The excavation did reveal a layer of dark yellowish brown (10YR ¾) river sand occurring at roughly 30-60 cm below surface. This material was thought to represent artificial fill for the plaza floor.




**Map 1: Cinco Cerros Plaza.**

Before the unit was backfilled, resistivity was used on the excavation wall. The excavation went to .9 meters below surface and four strata were observed. The matrix was damp throughout the column, though a protracted period of extremely hot and dry weather had persisted for several weeks before. Resistance measurements were taken from the upper four strata. Probes were inserted directly into the excavation wall and spacing remained constant at 10 centimeters. A general decrease in resistivity throughout strata 1-4 is immediately noticeable (Figure 5). This likely represents the effects of varying moisture content at depth. We would expect to see lower resistivity at depth because moisture will remain longer in deeper material. This may also represent more compact, undisturbed sediment. Stratum 4 was culturally sterile, and we have every reason to believe that it was never disturbed. As a result the layer will not have as great a void space between sediment grains. In a wet/dry seasonal environment, less porous material would not only be slower to absorb water in the wet season, but would also retain it longer in the dry season. The grain size composition of the material was also different. The matrix of stratum 4 was comprised of silt while the overburden was silty sand. Furthermore, evidence of iron staining in stratum 4 is also significant. Iron ions may be leaching out of the upper layers of material and being redeposited in lower strata, with the greatest concentration present in stratum 4. This also suggests that any moisture moving through the profile reaches this layer and becomes trapped long enough to precipitate iron. A material rich in ionic iron would certainly appear less resistant, though it is more likely that the difference in resistivity is caused by matrix porosity affecting moisture content.

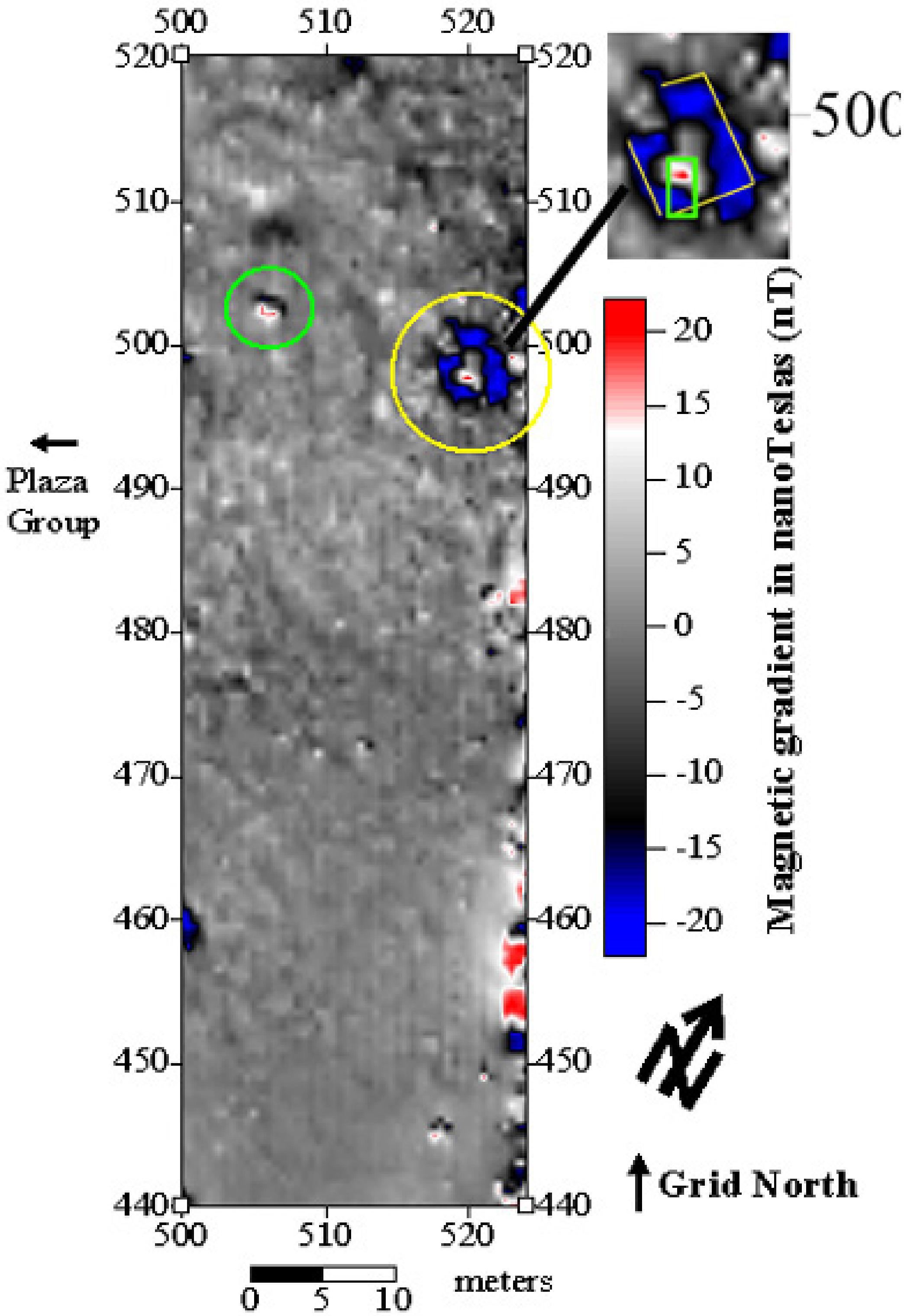
| Stratum | Depth Spread (cmbs) | Description | Resistivity (ρ) |
|---|---|---|---|
| 1 | 0-10 | 10YR2/1 Topsoil | 323.0 |
| 2 | 10-30 | 10YR3/2 Silty Sand | 245.7 |
| 3 | 30-60 | 10YR3/4 Silty Sand | 127.5 |
| 4 | 78- | 2.5Y4/4 Silt with 7.5YR5/6 inclusions | 38.3 |

**Figure 5: Resistivity measurements for Excavation 23.**

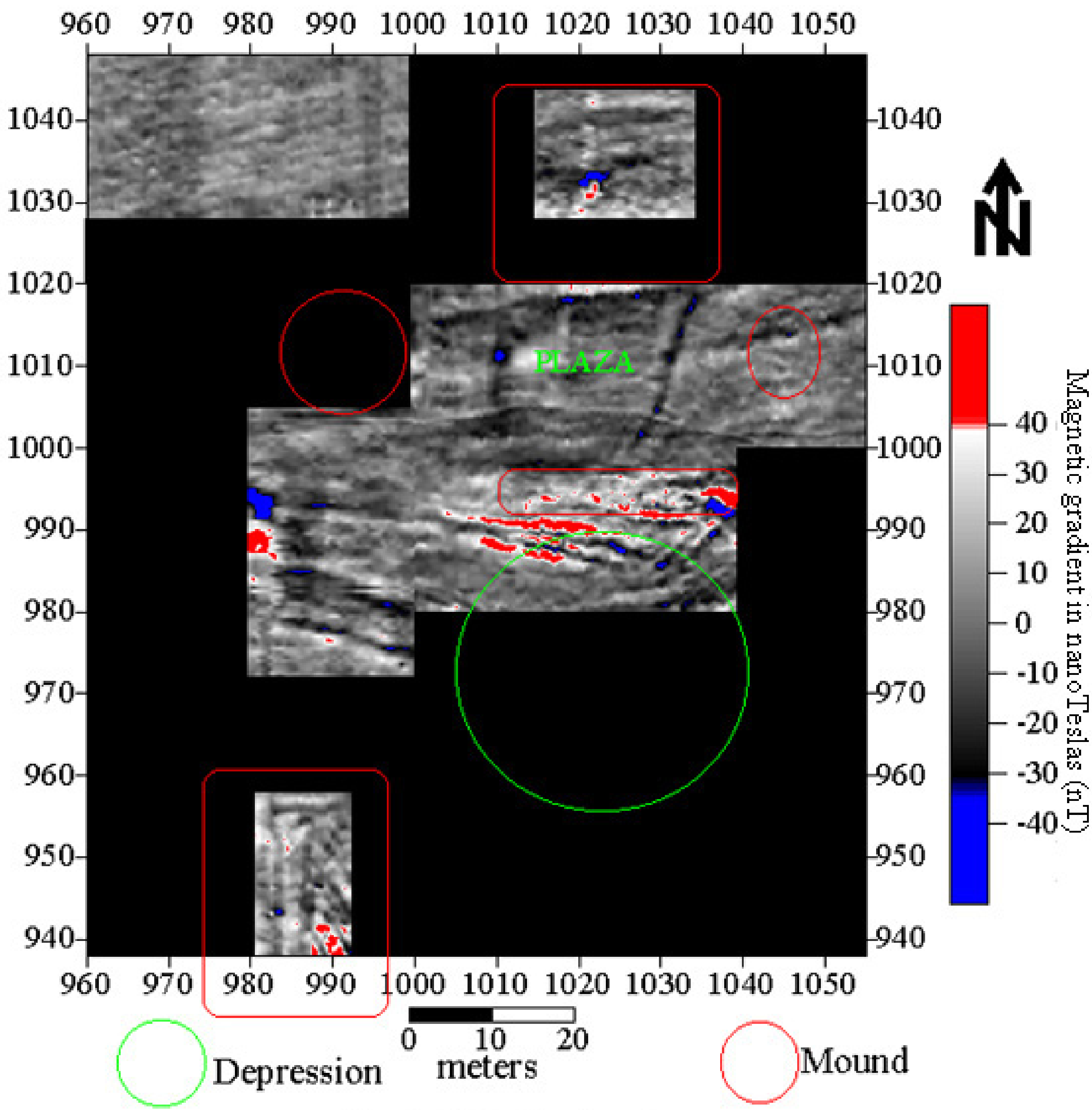
Another 1 x 2-meter test excavation was sited over the area of elevated readings indicated with a yellow circle. The immediate area was a slight rise in the ground surface. This excavation (CAP # 22) went to 70 cm below surface. There was an indication of the layer of possibly redeposited sand at 40-60 cm but the matrix exhibited orange staining (possible more iron). As with excavation 23, there was a low concentration of cultural material and it is possible that the magnetic anomaly was caused by changes in soil chemistry across the area or by an archaeological feature that was missed by such a small exposure. Resistivity was conducted at varying depths on a transect bisecting the magnetic anomaly, but readings were inconclusive.

The area along the grid south edge shows consistently raised magnetic values. After examining the data from Cinco Cerros and El Tecolote, it is clear that those areas around mounds exhibit a "halo" of elevated values caused by erosion of more magnetically susceptible, humic rich cultural strata from the mounds and deposition onto the surrounding topsoil. This humic matrix shows elevated magnetic values.

The other surveyed area at Cinco Cerros is located on the opposite side of the mounds that form the northeastern edge of the plaza (Map 2). The area measured 80 x 25 meters with its long axis also oriented 30 degrees west of North. A barbed wire fence caused the elevated values along the grid eastern edge. Of particular interest is the anomaly indicated by the yellow circle. In geophysical survey, the first method for interpretation is to locate patterned geometries such as circular, linear, or rectilinear features. In this case, the anomaly is rectilinear in shape and measure approximately 5 x 5 meters. The anomaly was classified as a possible structure. Close examination of the topography revealed that a very slight mound was located at the site of the magnetic anomaly. It was such a small rise that the initial walkover surveys of the site had missed it. A 1 x 2-meter test excavation (CAP 21, indicated with green box) was sited to straddle what was thought to be a wall. The unit went to a depth of 50 cm below surface at which a sterile layer was found. Great densities of domestic artifacts were found including 2 spindle whorl fragments and a fragment of a *metate*. This layer also contained a higher density of ceramics and a circular soil stain which was sampled for floatation analysis. Burned wattle and daub was found in great abundance and indicated that the structure may have been burned (rendering it more magnetically visible). Approximately 15 meters to the grid northwest of the house feature was another strong anomaly that was felt over several consecutive transects. It is marked on the Map 3 with a green circle. This anomaly may represent a hearth or other burning feature. It was not tested by excavation during this field season.




Map 2: Cinco Cerros Area 2.




**Map 3: El Tecolote Area 1.**

### *El Tecolote*

El Tecolote is located on the southern bank of the Río San Andrés approximately 2 kilometers west of Cinco Cerros. The Río San Andrés is a seasonally high-energy meandering river that within the past two years has shifted its course to create the oxbow that borders El Tecolote. There is further evidence to suggest that the shifting river had eroded a great deal of the northern section of the site. Walkover survey conducted by the Proyecto Arqueológico Hueyapan in 1998 found possible Postclassic period ceramics. Like Cinco Cerros, El Tecolote is comprised of a series of large earthen mounds organized into several main groupings (Figure 6). Today it is the site of a working beef cattle ranch and previous to that the area was used to grow sugar cane. Two areas of El Tecolote were surveyed.

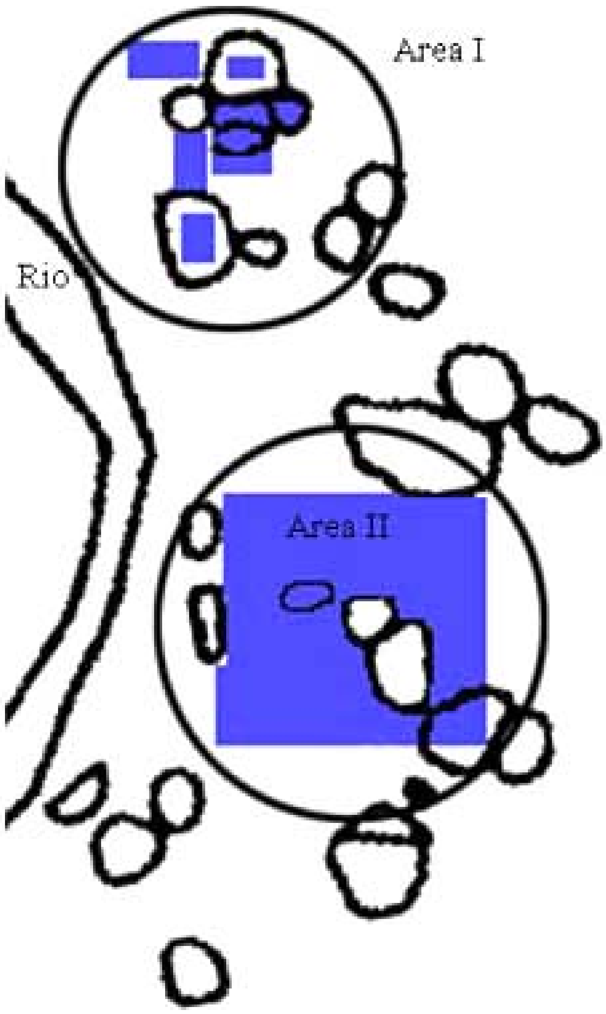



**Figure 6: El Tecolote Surveyed areas.**

*AREA I*

The first area is comprised of several grids sited around a rectangular plaza bounded on each side by earthen mounds (Map 3). The plaza group configuration is similar to Cinco Cerros, though the mound constructions are significantly smaller in size. The plaza group was oriented so that the long axis of the plaza ran East-West, instead of Cinco

Cerros 240-60 degree orientation. Immediately to the south of the discrete plaza group was a large circular depression measuring 30 meters across and several meters deep. To the southwest of the depression was another mound on which a fragment of burned brick was found during a walkover survey. We decided to include this mound to determine if there was any colonial construction present. In all, a total of 4800 meters$^2$ was surveyed around this plaza group.

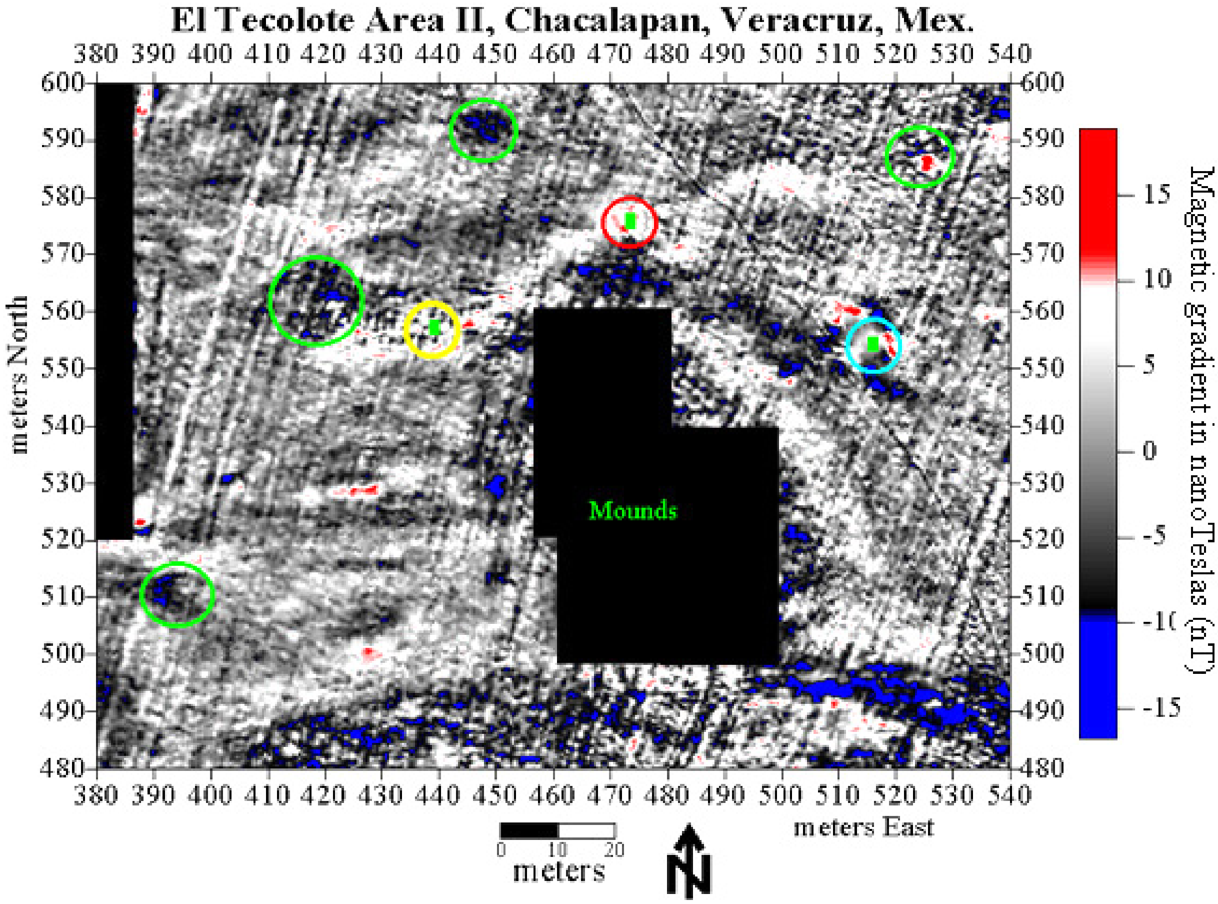
In the magnetic map depiction (Map 4), the mounds are identified with red enclosures and the depression by a green enclosure. The grid system was arbitrary and does not tie into the second area surveyed at El Tecolote. Several anomalies are immediately apparent. The banded red and blue running east-west at approximately North 990 is the result of instrument error. The northernmost five meters of the grid, to the south of the plaza, is on a significant upslope. The alternating high and low banding is caused by the terraced appearance of the ground surface. Most of the mound slopes at El Tecolote were slightly "terraced" when the area was in sugar cane production. As the sensor's distance to ground changes the readings fluctuate tremendously.

Within the plaza itself, four linear features are distinctly visible. The two running along the north and the south edge of the plaza represent modern footpaths. The two on the east and west edges are likely the signatures of cane furrows. This interpretation is based on the orientation of furrows present in second area of El Tecolote.

A grid to the northwest of the plaza group showed no significant anomalies. This was surprising considering that it was the surveyed grid located closest to the river.

The most tantalizing results came from the northern mound. A strong dipole reading was recorded at the approximate center of the mound. It is the approximate size, shape, and strength as the anomaly from the basalt test. Though the CAP did not test it with excavation this season, it will likely do so in the future.

A grid located to the south of the western mound contained so much modern garbage on the surface that the large anomaly detected at N990 E980 may be a modern garbage pit. Another grid to the west would have been able to better define the anomaly, but the presence of high bush prevented this.




**Map 4: El Tecolote Area 2.**

*AREA II (Map 4)*

This was the largest contiguous area surveyed. It measures 160 x 120 meters and is centered on an arrangement of 8 earthen mounds that do not form a discrete plaza group. An arbitrary datum point and grid system were used to located grids with respect to each other, but not to tie in with Area I. The large black area in the center of the map corresponds to the location of steep mounds that were impossible to survey effectively. The halo of redeposited humic matter is visible surrounding the central mounds. We were surprised to note the degree of mound weathering as indicated by the distribution of the halo. Magnetic readings were elevated as far as 30 meters from the mound.

The most noticeable aspect of this dataset is the linear striping that runs toward the northeast. These are representations of plow furrows. Due to a biochemical reaction that is responsible for creating topsoil, the material becomes slightly magnetically susceptible. Whenever the topsoil is disturbed or removed, it is apparent in magnetic data. Another long linear feature enters the dataset on the eastern side at about North

500 and runs northwest. This anomaly is a modern pathway and was also caused when the topsoil was disturbed.

Three excavations were sighted based on this dataset. These were CAP units 9-11 and their locations are noted on the map with green rectangles. Excavation 9 was sited on a very large anomaly that measures approximately 10 meters across. This anomaly produced readings that were elevated two orders of magnitude above the background noise. The excavation went to a depth of 1.7 meters below surface and failed to discover the source of the anomaly. Artifact density throughout the unit was also very low. Retesting of the area with the magnetometer after the excavation continued to show a very large anomaly, so it is likely that the small, 1 x 2 meter test unit missed the cause of the elevated readings. Resistivity testing showed a slight drop in resistance at a depth of 1 meter.

Excavation 10 was located in what was thought to be a likely location for a midden pit based on the highly magnetically susceptible area surrounded by dispersed elevated readings and its location near a mound. The 1 x 2-meter test unit was excavated to a depth of 1.6 meters below surface and then an additional 90 cm was excavated using a posthole digger. The density of cultural material was low, but still higher than in Excavation 9. Artifacts were also found in very deep levels, 1 meter and 1.4 meters below surface. While the surrounding area of diffuse high readings may represent a midden or humic material that sloughed off of the mounds, the cause of the very high spike was found early in the excavation. A piece of modern iron, probably from farm machinery was found close to the surface. This again illustrates the central theme of the practice of archaeological geophysics: one never knows what is causing an anomaly until one digs.

Excavation 11 was located on the eastern side of a low (less then 1.5 meters high), oblong mound. At 100 meters it was the closest test unit to the oxbow. Magnetics showed a series of dipole readings along the mound, and the excavation was sited to dig one of them. The 1 x 2-meter test unit was dug to a depth of 2.15 meters below surface and produced interesting findings. The first 60 cm were nearly free of artifacts. Evidence of burning was present from 60 cmbs to 1.84 meters below surface. Burned clay, ash, carbon, animal bones, teeth, and ceramics were found very deep in this unit. The sediment surrounding these artifacts was fire reddened and indicated that the material was in primary context (Figure 7). A circular stained feature was noted at 1.8 meters depth and thought to be a possible post hole.

The three excavations represent only a small sample of the anomalies at El Tecolote that should be tested. From excavated evidence, it seems that the cultural levels are unusually deep in the flat terrain, almost at the limit of the G-858 depth sensitivity. The Río San Andrés is known to flood and, aside from the anthropogenic mounds, the area is a flat plain. Settlement may have been concentrated on top of the mounds with only special activity areas or middens in the floodplain. Those special activity areas may then be buried under a meter of alluvium.

**Figure 7: Ash and burned feature, Excavation 11.**

In spite of the depth issue, the magnetic survey did indicate several possible archaeological features. Those are noted with green circles. Their identification is based on pattern geometries of the signals and comparison to the signals of known features, such as the burned "house" identified at Cinco Cerros. Sampling of these features may help further define the culture and chronology at El Tecolote.

## Conclusions and Suggestions for Further Research

The Chacalapan Geophysical Survey produced mixed results. In all, nearly 27,000 square meters were surveyed at very high resolution. The presence of modern metal in the survey area led us to locate two of the six test excavations over non-archaeological anomalies. Two excavations were inconclusive. Those two anomalies may also have been caused by modern debris, or the small-scale excavations may have simply missed the anomaly-causing targets. The remaining two units produced valuable data. In all, the time required to perform the survey was less than what would be required for traditional shovel pitting. Furthermore, shovel pits offer only glimpses into the subsurface, while the magnetic map is continuous. In this respect, we consider the survey a qualified success, and believe the technique has excellent potential for area survey in this region.

Spot resistivity measurements were of limited use. The extremely dry condition of the topsoil made it difficult for electrical energy to pass through. Resistivity should be attempted at varying times of the year to determine the season when soil moisture conditions are best for the technique.

It is our hope that researchers who are interested in applying magnetic gradiometry to their work in this area will compare their data to this survey in order to further refine an interpretive methodology that is better suited to the archaeology of southern Veracruz.

## Acknowledgements

This research was made possible by grant #99024 from the Foundation for the Advancement of Mesoamerican Studies, Inc. Support for the Chacalapan Archaeological Project was provided by the National Science Foundation (Grant # BCS9907262) and the Wenner Gren Foundation (Grant # GR6484). Permission for the research was received from the Instituto Nacional de Antropología e Historia in México. This research would not have been possible were it not for the guidance of and framework established by the Proyecto Arqueologico Hueyapan 1998 directed by Thomas Killion and Javier Urcid. We would also like to thank: Antonio Curet, Norman Hammond, Kenneth Kvamme, and Margaret Watters.

## List of Figures and Maps

**Sources Cited**


Berdan, Francis *et al.*

1996 *Aztec Imperial Strategies.* Dumbarton Oaks Research Library and Collection. Washington, D.C.

Breiner, S.

1973 *Applications Manual for Portable Magnetometers.* Geometrics, Inc., Sunnyvale, CA.

Clark, Anthony

1996 *Seeing Beneath the Soil: Prospecting Methods in Archaeology.* London: B.T. Batsford Ltd.

DeVore, Steven L. and Don H. Heimmer

1995 *Near-Surface, High Resolution Geophysical Methods for Cultural Resource Management and Archaeological Investigations.* Denver: National Park Service, U.S. Department of the Interior.

Geometrics, Inc.

1995 *Operation Manual: G-858 MagMapper.* Sunnyvale, California.

Hervanger, Jorg

1996 "Acquisition, Processing and Inversion of Magnetic Data in Archaeological Prospection", Institut für Geophysik Technische Universitat Clausthal.

Watters, Margaret S.

1999 Archaeogeophysicist, IMA Consulting, Minneapolis, Minnesota.

Weymouth, John W.

1986 "Geophysical Methods of Archaeological Site Surveying," In *Advances in Archaeological Method and Theory, Vol 9.* Michael B. Schiffer, ed., Academic Press, Inc.